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1.	Your reference	567GB
2.	Patent application number *(The Patent Office will fill in this part)*	0216488.7 — 16 JUL 2002
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Renishaw plc New Mills Wotton-under-Edge Gloucestershire, GL12 8JR
	Patents ADP number *(if you know it)*	2691002
	If the applicant is a corporate body, give the country/state of its incorporation	United Kingdom
4.	Title of the invention	Scale Reading Apparatus
5.	Name of your agent *(if you have one)*	E C Leland et al
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Renishaw plc, Patent Department New Mills Wotton-under-Edge Gloucestershire, GL12 8JR
	Patents ADP number *(if you know it)*	8187429001

16JUL02 E733700-2 D02651
P01/7700 0.00-0216488.7

		Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	–	–	–

		Number of earlier application	Date of filing *(day / month / year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	–	–

8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	Yes

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Claim (s)	0
Abstract	0
Drawing (s)	6

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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	0
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Request for substantive examination *(Patents Form 10/77)*	0
Any other documents *(please specify)*	0

11. I/We request the grant of a patent on the basis of this application.

Signature E. Leland Date 16.07.02

AGENT FOR THE APPLICANT

12. Name and daytime telephone number of person to contact in the United Kingdom A ILES 01453 524524

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SCALE READING APPARATUS

The present invention relates to apparatus and method for mounting a scale of a scale reading apparatus onto a machine. In particular, the invention relates to apparatus and method for mounting a rotary scale onto a machine.

A known form of opto-electronic scale reading apparatus for measuring relative displacement of two members comprises a scale on one of the members, having scale marks defining a pattern and a readhead in the other of the members. The readhead includes a light source for illuminating the scale and periodic diffraction means for interacting with light reflected from the scale marks to produce interference fringes at the readhead. Relative movement between the scale and the readhead causes the interference fringes to move relative to the readhead. Detecting means are responsive to the movement of the fringes and produce a measure of displacement.

For measuring rotary displacement, such a scale may be provided on a cylindrical surface which rotates in use with the shaft or other rotary part relative to the readhead. European Patent Application No. 1094302 discloses a ring for mounting on a rotary shaft of a machine which is provided with a scale on its outer circumference. The inner circumference of the ring and the outer circumference of the rotary shaft are both tapered in order to reduce error caused by the ring not sitting concentrically on the rotary shaft or eccentricity of the shaft seating itself. To compensate for eccentricity of the shaft, mounting

screws are provided in holes on the ring to adjust the position of the ring until it is concentric with the axis of rotation of the shaft.

The present invention provides a rotary ring system for use in scale reading apparatus comprising:

a rotary ring, provided with scale marks on a surface thereof, defining a pattern and readable by a readhead of such apparatus;

an intermediate ring system;

wherein the intermediate ring system is fitted between the rotary ring and the rotary part of the machine on which the rotary ring is to be mounted.

This system enables the radial adjustment of the rotary ring.

Preferably the intermediate ring system is a continuous ring. Alternatively the intermediate ring system may comprise a split ring or a plurality of arcuate segments.

The intermediate ring system may be provided with at least one tapered surface such that when the rotary ring and the intermediate ring system are mounted on a rotary part of the machine at least one tapered surface of the intermediate ring system is in contact with a surface of one or both of the rotary part of the machine and the rotary ring.

The intermediate ring system may be secured to the rotary part of the machine by adjustable securing means. Alternatively the rotary ring may be secured to the rotary part of the machine by adjustable securing

means.

The intermediate ring system may be flexible.

The flexible intermediate ring system enables it to take up the manufacturing tolerance of the rotary ring system. The flexible intermediate ring system may comprise, for example, a resilient ring.

The intermediate ring system may be tangentially compliant.

The tangentially compliant intermediate ring system evens out the circumferential tensions of the rotary ring and thus prevents bunching of the scale.

The intermediate ring system may comprise for example a plurality of ball bearings or alternatively a plurality of rollers.

The present invention will now be described by way of example and with reference to the accompanying drawings in which:.

Fig 1 is a cross-section of known apparatus for mounting a rotary ring on a rotary part of a machine;

Fig 2 is a cross-section of a rotary ring mounted on a rotary part of the machine tool with a tapered intermediate ring section;

Fig 3 is a plan view of the apparatus shown in Fig 2;

Fig 4 is a plan view of the apparatus shown in Fig 3 in which the intermediate ring system comprises a plurality of arcuate segments;

Figs 5-7 show cross-sections of variations of the

system shown in Fig 2;

Fig 8 is a cross-section of a rotary ring mounting apparatus in which the intermediate ring system comprises an o-ring;

Fig 9 is a cross-section of a rotary ring mounting apparatus in which the intermediate ring system comprises a deformable o-ring;

Fig 10 is a cross-section of a rotary ring mounting apparatus in which the rotary ring is mounted on a deformable disc sandwiched between two rigid discs;

Fig 11 is a cross-section of a rotary ring mounting apparatus in which the intermediate ring system comprises a metal spring;

Fig 12 is a cross-section of a rotary ring mounting apparatus in which the intermediate ring system comprises a garter spring;

Figs 13A and 13B are schematic illustrations showing the mounting of the intermediate ring system and rotary ring of Fig 12;

Fig 14 is a plan view of the rotary ring mounting apparatus shown in Fig 12;

Fig 15 illustrates a spring used as an intermediate ring system;

Fig 16 is a plan view of the rotary ring mounting apparatus using the intermediate ring system shown in Fig 15;

Fig 17 is a cross-section of the rotary ring mounting apparatus in which the intermediate ring system comprises ball bearings;

Fig 18 is a cross-section of the rotary ring mounting apparatus in which the intermediate ring system comprises rollers;

Fig 19 is a plan view of the apparatus of Fig 18;

Fig 20 is a cross-section of the rotary ring mounting apparatus in which the intermediate ring system comprises radially adjustable ball bearings;

Fig 21 is a cross-section of the rotary ring mounting apparatus in which the intermediate ring system comprises radially adjustable rollers; and

Fig 22 is a cross-section of the rotary ring mounting apparatus comprising a combination of the apparatus shown in Figs 2 and 8.

Fig 1 shows a rotary ring 12 mounted on a tapered shaft 10 as disclosed in our earlier European Patent Application No. 1094302. The rotary ring 12 is provided with scale marks 14 which define a pattern and can be read by a readhead (not shown). The scale marks may, for example, define a periodic pattern for an incremental scale or may define a pseudorandom sequence or discrete codewords to form an absolute position scale. The inner surface 18 of the rotary ring 12 is provided with a tapered surface at an angle to the axis A of the ring. The tapered surface removes the need for close tolerance on the diameters of the ring 12 and the shaft 10. In addition, the taper reduces errors caused by the rotary ring 12 not sitting concentrically on the rotary part on which it is mounted. The angle of the taper α relative to the axis A of the ring serves to magnify a small radial displacement into a large axial displacement and thus allows precise centring of the ring 12 relative to the shaft taper 10.

Embodiments of the present invention will now be described in which identical reference numbers are used to indicate similar parts. In embodiments 1-4 a tapered intermediate ring is provided between a shaft

of a rotary ring provided with scale markings on its surface.

A first embodiment of the invention is illustrated in Figs 2 and 3. A rotary ring 12 having scale marks 14 defining a periodic pattern on its outer circumferential surface is mounted on a shaft 10 of the machine. The scale marks may be provided directly on a surface of the rotary ring or may be provided in a tape which is secured to a surface of the rotary ring. An intermediate ring 24 is fitted between the rotary ring 12 and the shaft 10. The inner circumferential surface 26 of the intermediate ring 24 is tapered and the shaft 10 is provided with a corresponding tapered surface 20. The intermediate ring 24 is provided with apertures 15 into which mounting screws 16 may be inserted. The mounting screws 16 and the apertures 15 are generally parallel to the axis of rotation A of the shaft 10. The mounting screws 16 may be adjusted to pull the intermediate ring 24 further down the tapered surface 20 of the shaft 10 and thus pushing the adjacent portion of the rotary ring 12 radially outwards. This apparatus thus allows the rotary ring 12 to be adjusted radially. In addition, pulling the intermediate ring 24 down the tapered surface 20 of the shaft 10 takes up the manufacturing tolerance of the rotary ring 12. The mounting screws 16 may be adjusted individually to centre the rotary ring 12 with axis of rotation A of the shaft 10.

In place of a one-piece intermediate ring 24, arcuate segments 30 may be provided at each mounting screw 16 to the same effect, as shown in Fig 4.

Alternatively the intermediate ring could comprise a split ring.

The use of a tapered intermediate ring has the advantage that a rotary ring with parallel sides may be mounted on a tapered machine shaft. Such a rotary ring may be cheaper and easier to manufacture than a tapered rotary ring.

A second embodiment of the invention is shown in Fig 5. In this embodiment the outer surface 20 of the machine shaft 10 is not tapered and the inner surface 19 of the rotary ring 12 is provided with a taper. The intermediate ring is thus provided with a corresponding tapered outer circumferential surface 28 and non-tapered inner circumferential surface 26. As in the previous embodiment, the mounting screws 16 are tightened to pull the intermediate ring downwards and push the rotary ring 12 outwards.

A third embodiment of the invention is shown in Fig 6. In this embodiment both the outer surface 20 of the machine shaft 10 and the inner surface 18 of the rotary ring 12 are provided with a taper. Both inner and outer circumferential surfaces 26,28 of the intermediate ring 24 are correspondingly tapered. As before, tightening of the mounting screws 16 pulls the intermediate ring 24 down the tapers and pushes out the rotary ring 12.

A fourth embodiment of the invention is shown in Fig 7. As in the second embodiment of the invention, only the outer surface 28 of the intermediate ring 28 and the inner surface 18 of the rotary ring 12 are tapered.

However in this embodiment the taper of the intermediate ring is such that its diameter is greater at the bottom than at the top. The rotary ring is provided with the mounting screws 16 such that tightening of the mounting screws 16 pulls the rotary ring 12 down the taper and pushes it radially outwards.

The intermediate ring system may be flexible as illustrated in embodiments 5-8. In a fifth embodiment a flexible intermediate ring is provided between the shaft and the rotary ring. The flexible intermediate ring may comprise, for example, an o-ring 32, as shown in Fig 8. The shaft 10 may be provided with an annular recess 34 to accommodate the flexible o-ring 32. The rotary ring 12 is pushed onto the shaft over the o-ring 32. The shaft 10 may have a tapered upper surface 35 to enable the o-ring 32 and rotary ring to be mounted on the shaft more easily. Use of a flexible intermediate ring system, such as an o-ring, has the advantage that it takes up the manufacturing tolerance of the rotary ring 12.

A sixth embodiment of the invention is illustrated in Fig 9. In this embodiment a flexible intermediate ring system (for example an o-ring 32) is positioned between the shaft 10 and the rotary ring 12. A clamp 36 is in contact with the o-ring 32 and may be pushed down onto the o-ring 32 by mounting screws 16. The o-ring 32 is deformed by the pressure from the clamp 36 and thus pushes the rotary ring 12 outwards.

A seventh embodiment of the invention is illustrated in Fig 10. In this embodiment the rotary ring 12 is mounted on a deformable disc 38 (for example a rubber

disc) sandwiched between two rigid discs 44. The rigid sheets 44 may be clamped together to squash the deformable sheet 38, causing it to bulge outwards, thus pushing the rotary ring 12 radially outwards. The deformable disc may be replaced by a deformable ring as shown by the dashed lines 40.

An eighth embodiment of the invention is shown in Fig 11. In this embodiment the intermediate ring system comprises a metal spring 46. The inner surface of the rotary ring 12 may comprise a recess 48 to accommodate the spring 46. As in embodiments 6 and 7, pressure indicated by arrows P may be exerted in the spring in the direction of the arrows to deform the spring 46, thus pushing the rotary ring 12 radially outwards.

The intermediate ring system may be tangentially complaint, as illustrated in Figs 2-10. In the embodiments shown in Figs 12-16, the intermediate ring between the shaft 10 and rotary ring 12 comprises a tangentially compliant spring. This has the advantage that forces exerted on the rotary ring are spread out over the circumference and bunching of the scale is reduced. In a ninth embodiment of the invention, illustrated in Figs 12-14, the tangentially compliant spring comprises a garter spring 50.

The garter spring 50 is easily mounted on the machine shaft 10 by placing the garter spring 50 and rotary ring 12 around the top of the machine shaft 20 and pushing the rotary ring 12 over the machine shaft 10 to pull the garter spring 50 into position as shown in Figs 13A and 13B. The machine shaft 10 may be provided with a tapered surface 51 at the top to enable the

garter spring 50 and rotary ring to be mounted more easily.

In a tenth embodiment of the invention, illustrated in Fig 16, the tangentially compliant spring has a corrugated cross-section 52 as shown in more detail in Fig 15.

The intermediate ring system provided between the shaft 10 and the rotary ring 12 may comprise a plurality of elements which are radially rigid and tangentially compliant.

An eleventh embodiment of the invention is illustrated in Figs 17 and 18 which show an intermediate ring system comprising an array of ball bearings 54.

The ball bearings may be located in a cage 56. As in the previous embodiment, the tangential compliance of the ball bearings 54 causes the forces exerted on the rotary ring 12 to be spread out, thus preventing bunching of the scale 14.

As the ball bearings will allow rotation of the rotary ring with respect to the machine shaft, locking means may be provided to ensure the rotary ring rotates together with the machine shaft. The locking means may comprise a pin, or magnet, for example.

A twelfth embodiment of the invention is shown in Fig 19 which shows a variation in which the ball bearings 54 have been replaced by rollers 58 to the same effect.

In a thirteenth embodiment of the invention illustrated

in Fig 20, the ball bearings 54 are mounted between a surface 64 of the machine shaft 10, a surface 62 of a clamping ring 60 and the rotary ring 12. Mounting screws 16 are provided in the clamping ring 60 which may be tightened to pull the clamping ring 60 downwards, thus pushing the ball bearings 54 and rotary ring 12 outwards. This system thus provides both anti-bunching and radial adjustment.

A fourteenth embodiment of the invention illustrated in Fig 21 also provides both anti-bunching and radial adjustment. Rollers 58 are located between the rotary ring 12 and a tapered intermediate ring 24. The intermediate ring 24 is tapered on its inner surface 26 with the outer surface 20 of the machine shaft 10 being correspondingly tapered. A clamping ring 66 and mounting screws 16 are provided to push the intermediate ring 24 down the taper and provide radial adjustment of the rotary ring 12. The same effect may be achieved by using ball bearings in place of the rollers.

Many other combinations of the various embodiments described are possible. For example a flexible o-ring 32 may be provided between the rotary ring 12 and a tapered intermediate ring 24 as illustrated in Fig 22.

Although the embodiments describe a rotary ring with a scale on its outer surface, the scale may be provided on an alternative surface, for example radial scale marks may be provided on the upper surface of the ring. Alternatively the rotary ring may be provided with scale marks on its inner surface, the ring being located inside a rotary bore of a machine with the

intermediate ring system being located between the bare inner surface and the rotary ring's outer surface.

The intermediate ring system may be configured such that the rotary ring is supported out of the plane of the rotary part of the machine.

This invention is not limited to use with optical scales. It is also suitable, for example, for use with magnetic scales.

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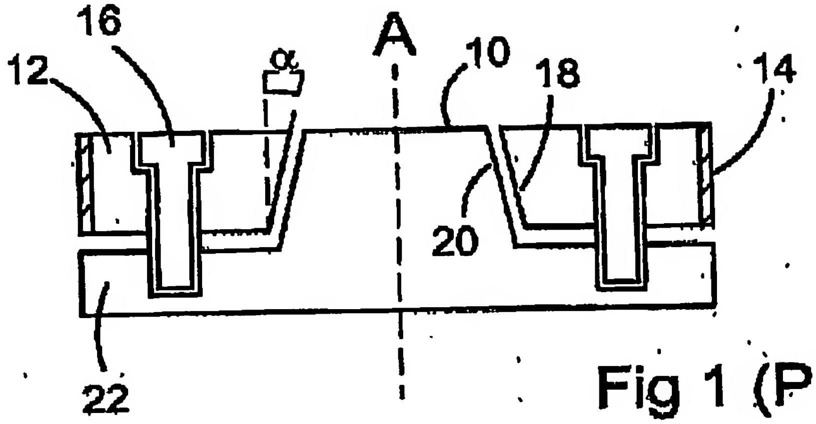

Fig 1 (PRIOR ART)

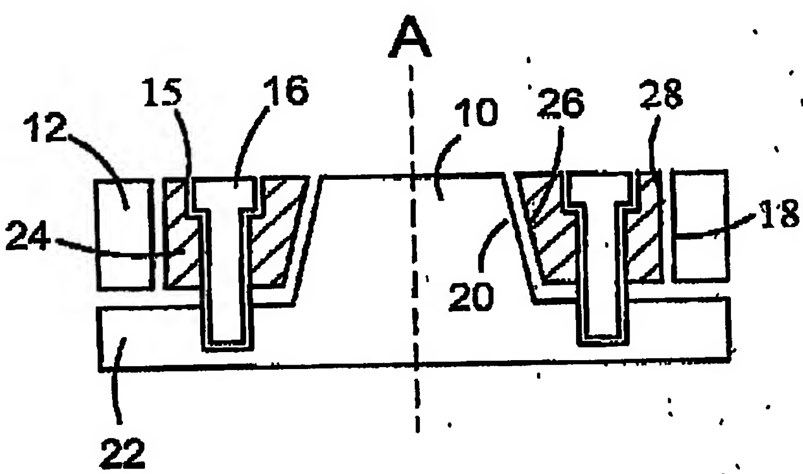

Fig 2

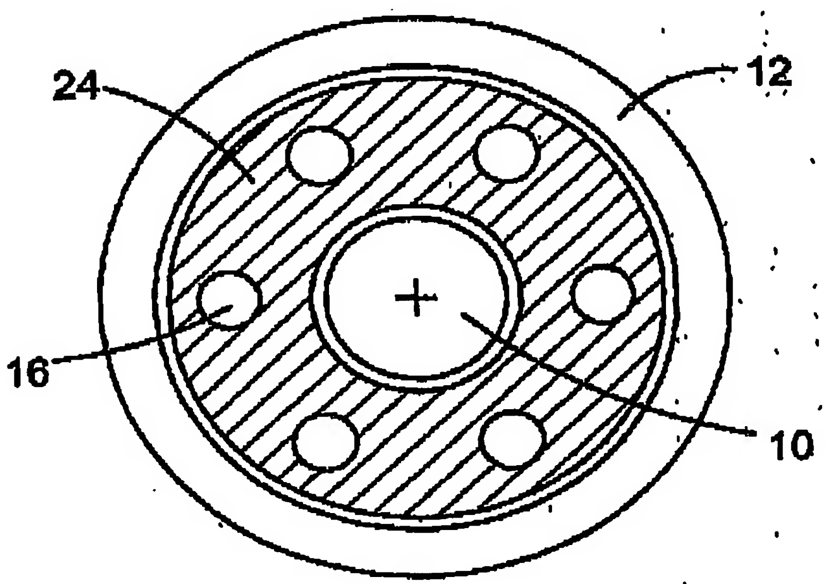

Fig 3

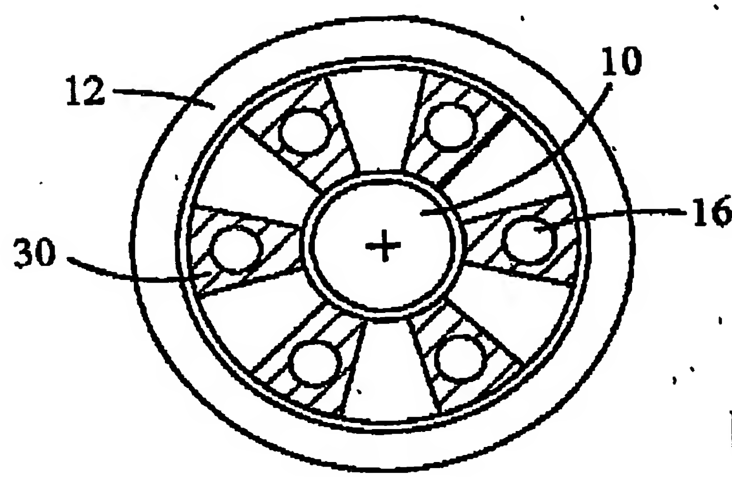

Fig 4

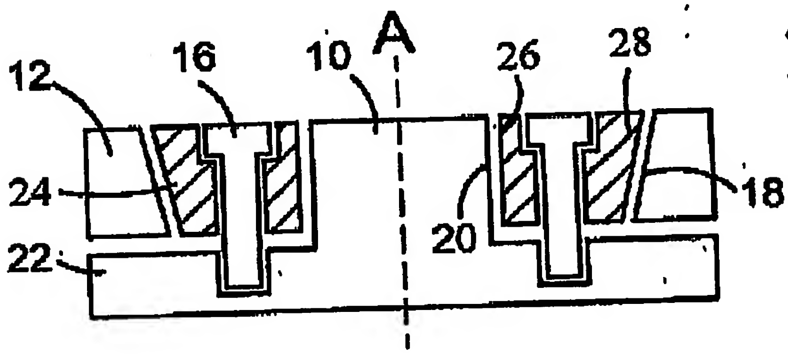

Fig 5

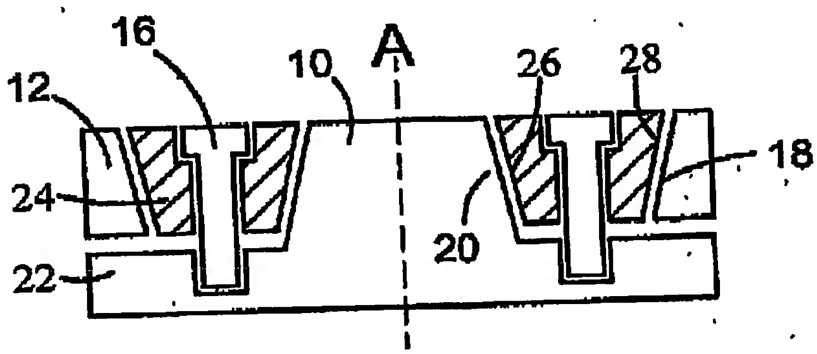

Fig 6

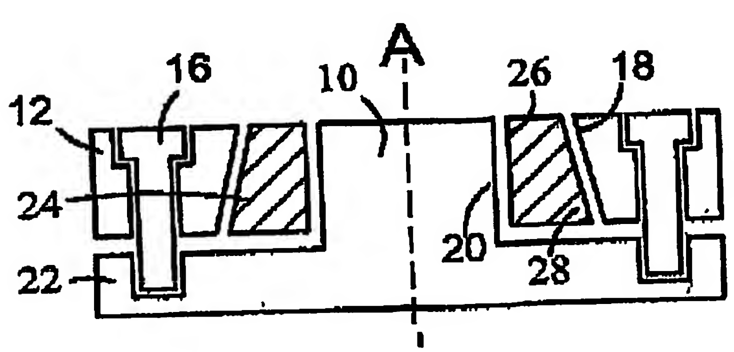

Fig 7

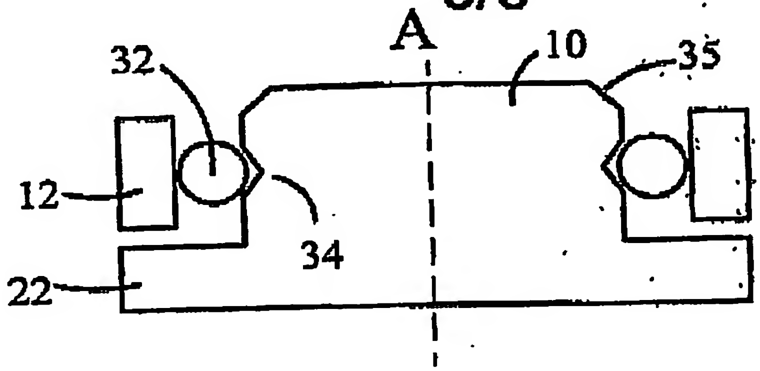

Fig 8

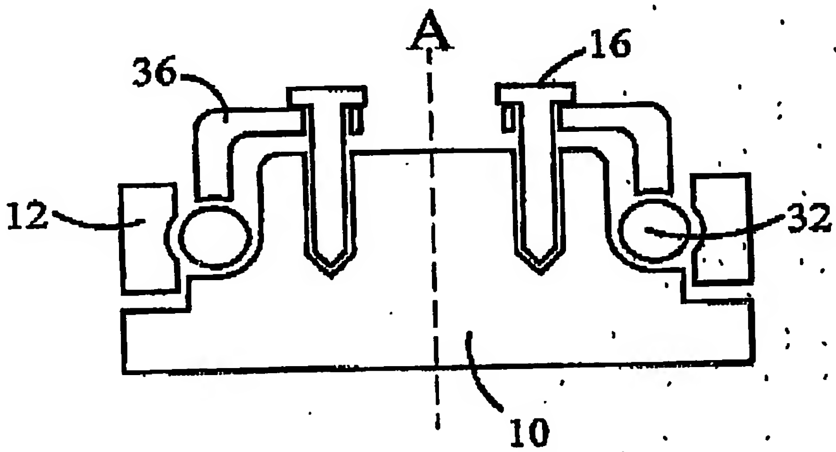

Fig 9

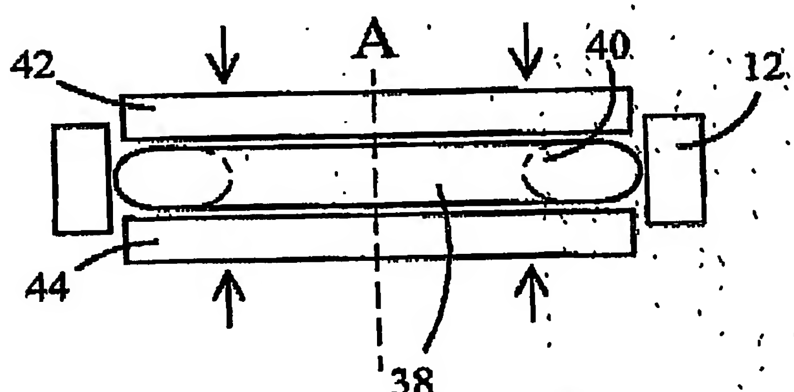

Fig 10

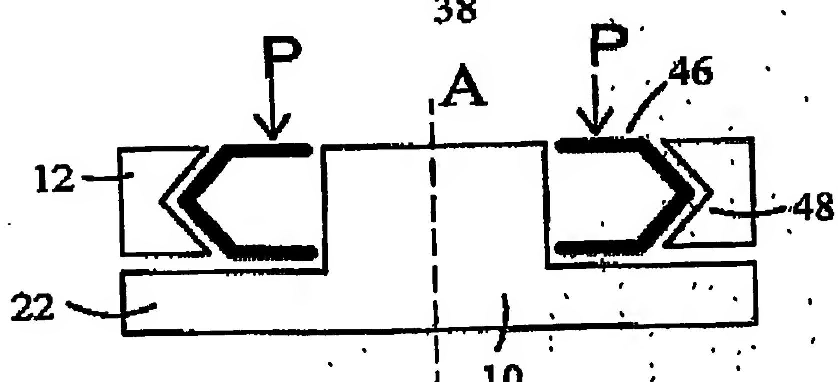

Fig 11

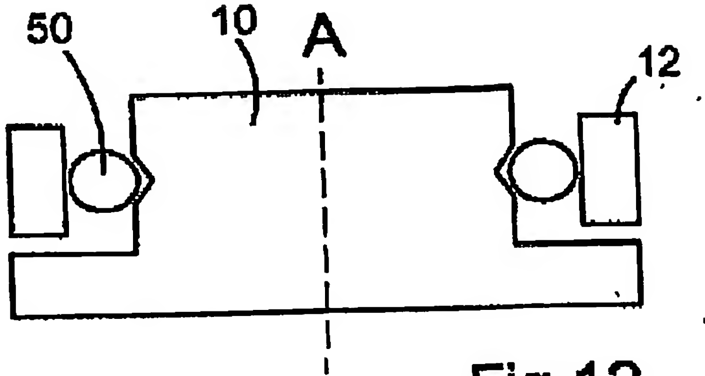

Fig 12

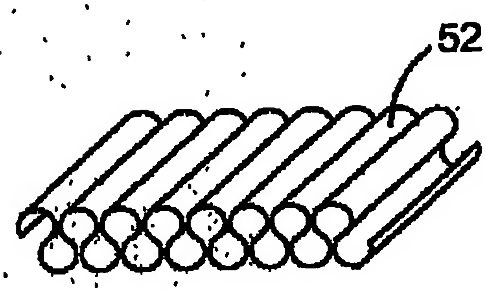

Fig 15

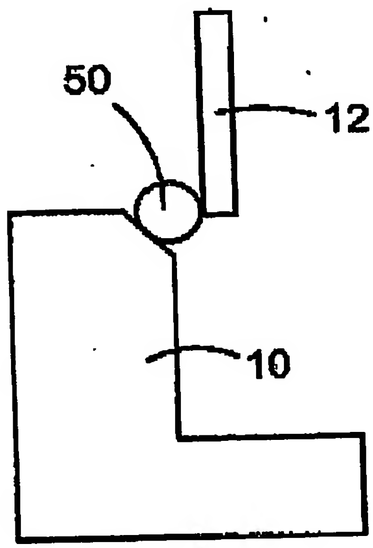

Fig 13A

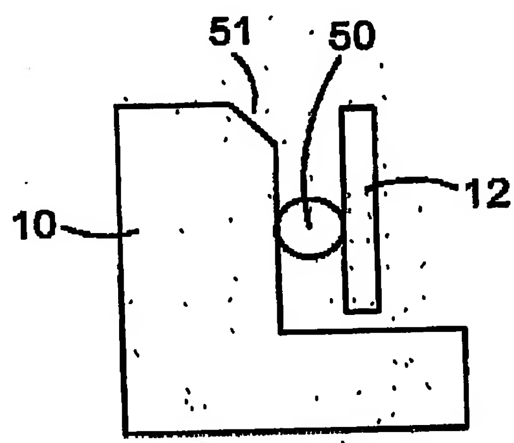

Fig 13B

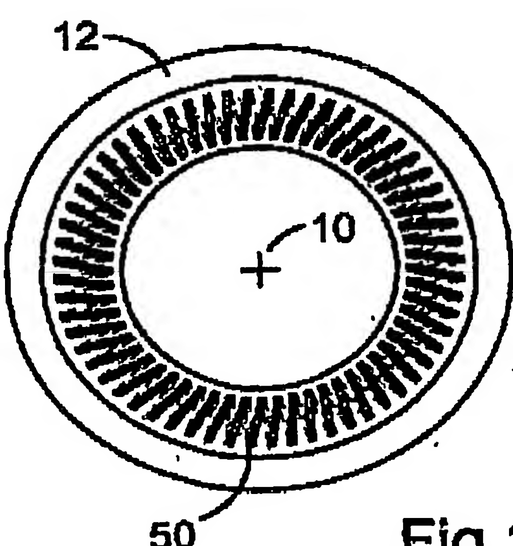

Fig 14

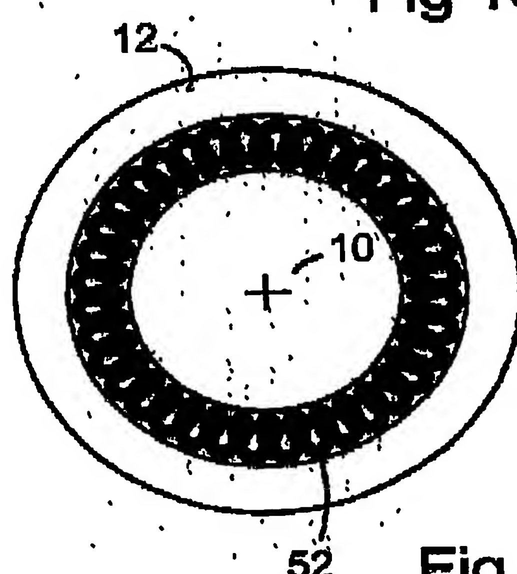

Fig 16

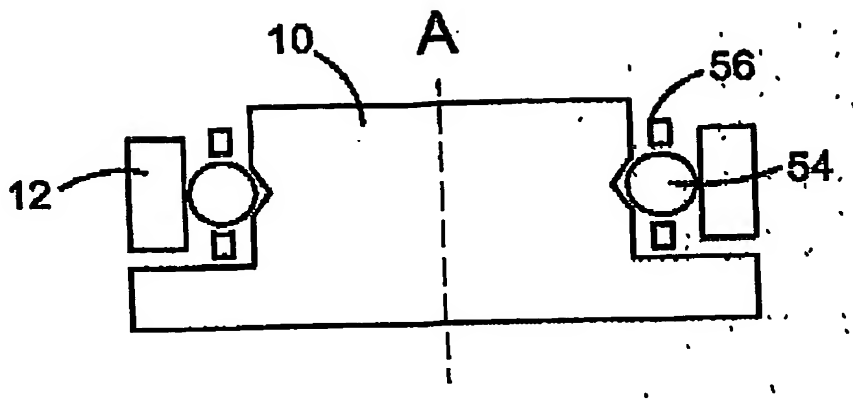

Fig 17

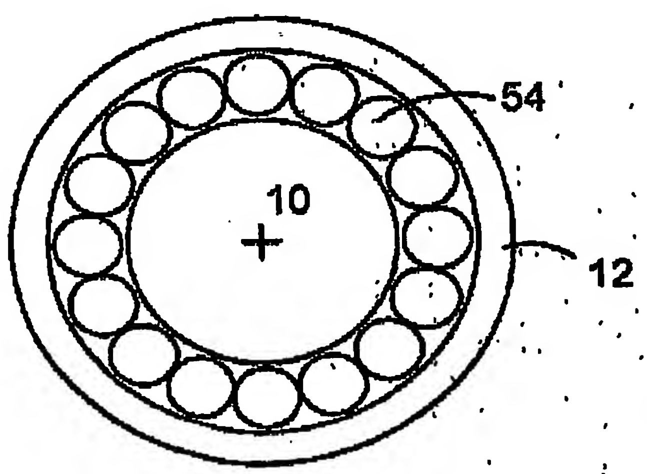

Fig 18

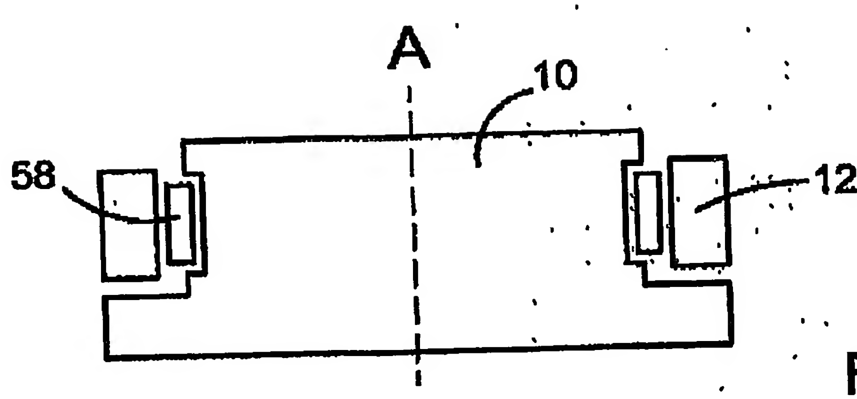

Fig 19

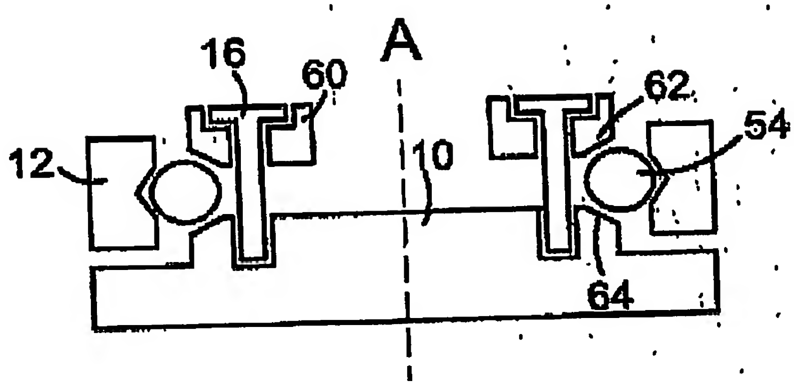

Fig 20

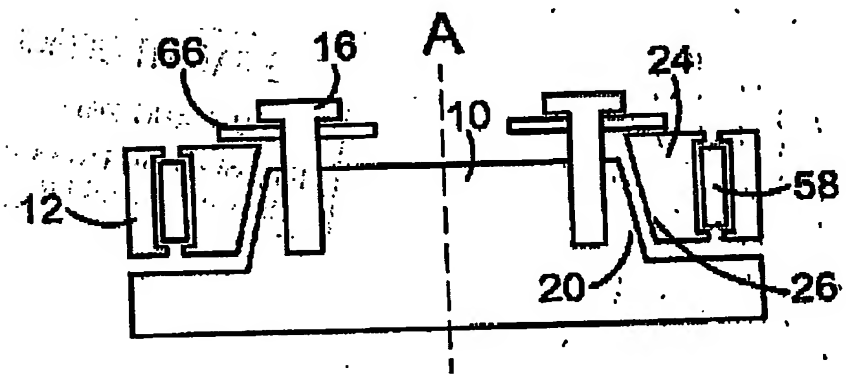

Fig 21

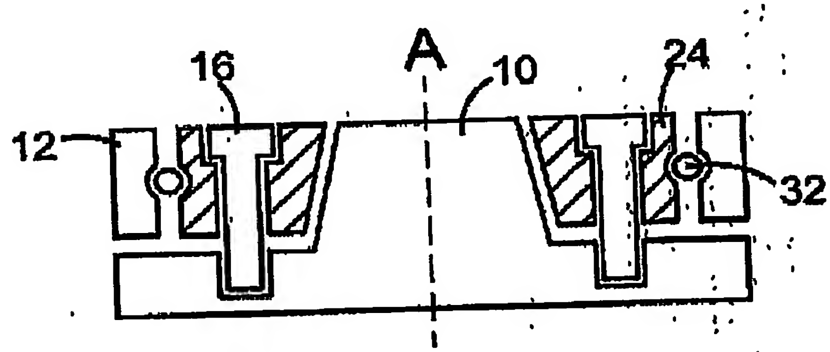

Fig 22